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Effects of External Radio Transmitters on Fish

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Effects of External Radio Transmitters on Fish

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ABSTRACT: Yellow perch (*Perca flavescens*) and largemouth bass (*Micropterus salmoides*) were studied to determine the effects of externally attached radio transmitter tags. Perch that had been tagged with dummy radio tags were more susceptible to predation and more sensitive to environmental stress than were controls. Feeding and respiration rates were similar among dummy tagged and control groups of perch over a 6-week period. The feeding rate of dummy tagged largemouth bass was lower than that of untagged fish over a 3.5-week period. On the basis of these studies, we conclude that weights of external transmitters in water should be less than 1.5% of the fish weight. Design considerations should include streamlining components and an anterior attachment wire at the extreme leading edge of an external transmitter to prevent entanglement of the tag in surrounding vegetation.

Biotelemetry has been used extensively to monitor movements, activity, and reactions to environmental variables of both free-ranging and captive animals. Although biologists studying terrestrial animals can often locate and visually observe their study animals for transmitter effects, fisheries researchers seldom have the same opportunity. Because behavioral characteristics of tagged specimens are studied for the purpose of extrapolation to untagged individuals, the effect of the tag and tagging process must be known before such extrapolation can be made with confidence.

Transmitter attachment procedures differ among telemetry studies, depending on the species, environment, type of research, and state of the art. External transmitters often must be used for small or gravid fish, especially when facilities are not available in the field for surgical implants. Several authors have addressed the effect of transmitters on fish relative to one or more of the following: swimming ability, feeding behavior, survival, tag retention, and attachment effects. Stasko and Pincock (1977) summarized these studies of transmitter effects and indicated the need for more research. Recently Dombeck (1979) observed a decrease in survival of northern pike (*Esox lucius*) with dummy internal transmitters, but found no difference between pike with dummy external transmitters and controls. Freid et al. (1976) reported that smolts of the Atlantic salmon (*Salmo salar*), a physostomous fish, adjusted for the negative buoyancy caused by the weight of the transmitter tag by gulping air. Neutral buoyancy was regained in bluegills (*Lepomis macrochirus*), a physoclistic fish, in less than 24 h by secretion of gas into the air bladder to adjust for transmitter weight (Gallepp and Magnuson 1972). However, McCleave and Stred (1975) determined that large internal and external tags caused a significant decrement in swimming ability of Atlantic salmon smolts in stamina chambers. Wrenn and Hackney (1979), who used dummy radio transmitters surgically implanted in sauger (*Stizostedion canadense*), concluded that survival and weight loss were not significantly different among transmitter-implanted and control fish. Further investigations of this nature are warranted because the state of the art of electronics for telemetry has surpassed our knowledge of the biological effects of transmitter packages.

The objectives of our studies were to determine the effects of radio transmitter packages on the physiology and predator-prey relations of yellow perch (*Perca flavescens*) and largemouth bass (*Micropterus salmoides*). The studies contrasted the responses of fish with dummy radio tags, sham tags, or both with those of control fish exposed to similar environmental conditions. Some control groups were tagged with Atkin tags (small plastic tags) attached to the upper back immediately anterior to the dorsal fin. Fish with dummy radio tags were also equipped with a numbered, external, simulated radio tag fitted immediately ventro-

lateral to the dorsal fin (Winter et al. 1978; Gray and Haynes 1979). Dummy radio tags were designed to weigh, when immersed in water, about 0.5–1.5% of the fish weight. This transmitter-to-fish weight ratio was selected on the basis of transmitters available for use with small fish. The processing of fish with sham-tags and dummy radio tags was identical except that after processing the tag was removed from the sham-tagged fish before they were used in experiments. The level of significance for differences observed between these groups was accepted as $P < 0.05$ unless otherwise indicated.

We performed five experiments: (1) survival of dummy radio tagged versus control yellow perch; (2) differential mortalities of dummy radio tagged and control fish when they were exposed to predation by northern pike; (3) feeding and growth rates of dummy radio tagged and control largemouth bass; (4) respiration and feeding and growth rates of dummy radio tagged, sham-tagged, and control groups of yellow perch; and (5) influence of varying the weight of dummy radio tags on yellow perch to determine maximum carrying capacity.

Experiment 1: Survival

Methods

Equal numbers of yellow perch (28; mean weight, 284 g/fish) with dummy radio tags and Atkin tags (control fish) were released into a pond (0.5 ha, 2 m deep) at the Environmental Research Laboratory – Duluth, Minnesota. The pond substrate was gravel with several inches of silt and with submerged vegetation and filamentous algae in the shallows. Substantial amounts of planktonic algae were noted. Temperatures in the pond averaged 22°C at the surface and 18°C at the bottom. Dissolved oxygen in the pond was very low at the bottom, averaging 1.4 mg/L in August, with a low of 0.1 mg/L early that month. Dummy radio tagged and control fish were released on 6, 7, and 30 August 1975.

Results

When the pond was drained on 1 November (86 days after initial release) only 2 of 28 dummy radio tagged fish were recovered, whereas 23 of 28 controls survived (Table 1). Between 11 August and 10 September nine dead dummy radio tagged fish and two dead control fish were found in the pond. Four of the nine dummy radio tagged fish had enlarged holes around the attachment wires and filamentous algae caught between the fish and the anterior end of the tag. One of the observed mortalities was a dummy radio tagged fish that had lost its tag; holes were evident where the attachment wires had pulled through the body and the dorsal fin.

Table 1. Survival of two groups of 28 externally tagged yellow perch recovered 86 days after first release in an outdoor pond (experiment 1).

Fish group	Number of fish recovered		Survival (%)
	Alive	Dead	
Dummy radio tag	2	9	7
Atkin tag (control)	23	2	82

Experiment 2: Predation

Methods

The predation experiment was carried out in a pond about 0.05 ha in area and 1 m deep. The bottom, which was bedrock and gravel with very little silt, was about 70% covered with dense mats of rooted aquatic vegetation. The water was clear throughout the experiment and no major algal blooms were observed. Temperature averaged 20.5°C. Because of the shallow depth and isothermal structure of the pond, dissolved oxygen, though not measured, was assumed to be adequate during the study period. In this experiment 62 yellow perch (mean weight, 108 g) were used as prey species and 5 northern pike as predators. On 7 and 29 August and 7 September 1975, equal numbers (10, 12, 9, respectively) of dummy radio tagged and control yellow perch were released into the pond. Shoreline observations of the pond were made about every 2 days for mortalities and the pond was seined twice during the experiment. It was completely drained on 12 September and all surviving fish were sacrificed for examination. Stomachs of the northern pike were examined for evidence of predation. Observed mortalities were subtracted from the total fish released to obtain the number of fish available to the predators.

Results

When the pond was drained, five dummy radio tags were found on the bottom with no tissue attached; one had been seen several days earlier on a living perch. Twenty-nine of 31 control fish and 11 of 27 dummy radio tagged fish were recovered alive (Table 2). Mortality of dummy radio tagged fish was significantly higher than that of control fish. The mortalities could not be confirmed as due entirely to predation; however, that predation was involved to some extent was evidenced when, upon capture, the largest pike regurgitated a partly digested perch with a dummy radio tag. The stomach of another pike yielded a dummy radio tag with a small amount of tissue still attached. Other tags retrieved from the bottom of the pond may have represented egesta of prey fish or could have been jarred loose from perch during attack by the predators.

Table 2. Vulnerability to predation of two groups of 31 externally tagged yellow perch confined for 37 days in an outdoor pond containing five northern pike (experiment 2).

Fish group	Number of fish		Survival (%)
	Available to predators	Recovered	
Dummy radio tag	27[a]	11	41
Atkin tag (control)	31	29	94

[a] Four of the perch died not as a result of predation.

Experiment 3: Bass Feeding

Methods

The feeding experiment with largemouth bass was carried out in tanks in the Environmental Research Laboratory – Duluth. Ten laboratory-reared and 12 wild-caught largemouth bass were divided equally into a dummy radio tagged group and a control group on 6 August. Initially there was no significant difference in the mean lengths and weights of controls and dummy radio tagged fish. The fish were fed a measured amount of minnows once every other day from 19 August through 13 September and allowed to feed for alternate 1- and 6-h periods; the remaining minnows were removed from the tanks after these time limits.

Results

In the laboratory-reared group of fish, controls consumed more minnows than dummy radio tagged fish in 13 of 13 trials (Fig. 1). For the wild fish, controls ate more minnows than dummy radio tagged fish in 10 of 13 trials. Growth was significantly less for the tagged fish between 6 August and 13 September in both laboratory-reared and wild-caught groups (Table 3).

Controls seemed more active than dummy radio tagged fish, but the tagged fish appeared to have no difficulty in feeding and were observed feeding 12 h

Table 3. A weight comparison of largemouth bass before (6 August 1975) and after (13 September 1975) a controlled feeding experiment in laboratory tanks (experiment 3). Number of fish examined given in parentheses.

Group and number of fish	Mean weight (g)		Weight change	
	Initial	Final	Mean (g)	Percent
Laboratory-reared				
Tagged (5)	411	432	+21	+ 5
Control (5)	365	451	+86	+24
Wild-caught				
Tagged (6)	229	228	– 1	0
Control (6)	211	251	+40	+19

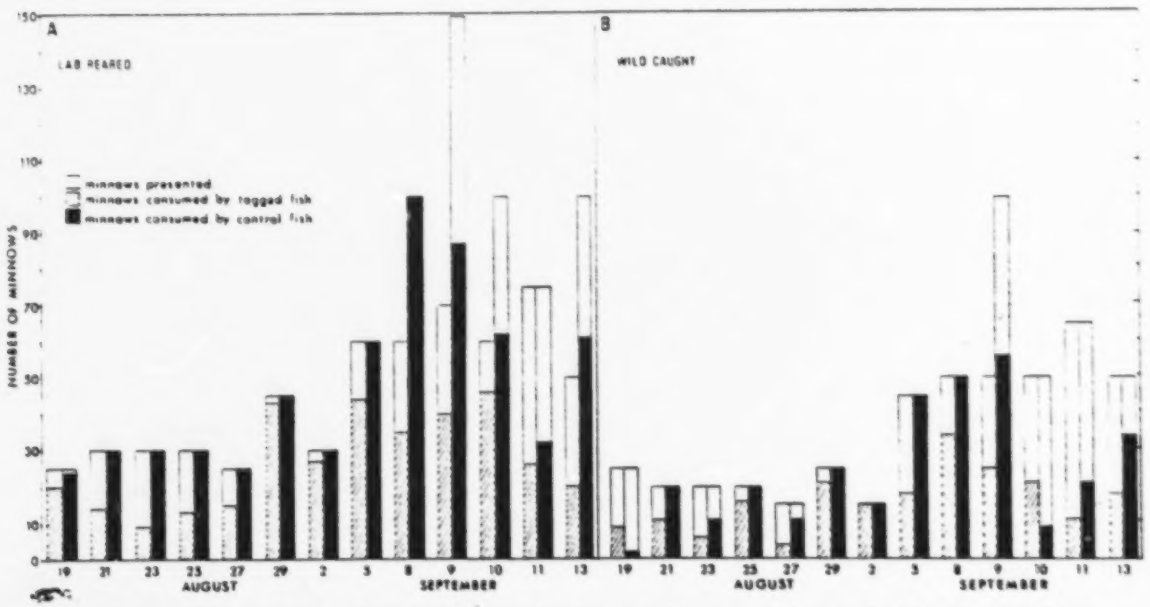

Fig. 1. Minnow consumption by dummy radio tagged and untagged largemouth bass under laboratory conditions.

after they were tagged. When the fish were examined on 13 September, sores were observed under the dummy radio tags and attachment plates; the tags had loosened during the experiment and the dummy radio tags had chafed the underlying surfaces. Some fungus was present on the dummy radio tags and around the attachment wires, but some fungus infections were also found on the controls. One fish with a dummy radio tag had shed the tag and the wound had healed, leaving only a slight scar and a torn section on the dorsal fin.

Experiment 4: Perch Feeding and Growth Rates and Respiration

Methods

Experiments on yellow perch respiration and on feeding and growth rates were carried out at our field laboratory in Cohasset, Minnesota, from 28 September to 7 November 1976. Fish were kept in a single 600-L stainless steel holding tank divided into three compartments and supplied continuously with untreated Mississippi River water. The temperature in the tank varied with the river temperature (range, 4–19° C). The fish were divided into dummy radio tagged, sham-tagged, and untagged control groups, with five fish in each group. Each individual was weighed and measured before and after the 6-week experiment. Initially there was no significant weight difference between the treatment groups. Each group was supplied with 10 minnows a day and the number consumed was tallied the following day. The respiration rate of each fish was recorded daily (the number of operculum cycles over a 30-s interval).

Results

Respiration rates in dummy tagged, sham-tagged, and control fish varied with temperature independent of treatment (Fig. 2). A single-factor analysis of variance indicated no difference in respiration rates over the 6-week period. However, due to the great variability caused by temperature fluctuation in the tank, respiration rates were also analyzed on a daily basis. Significant differences in respiration were observed between groups on only 3 of 33 days: on 6 October, rates of dummy radio tagged and sham-tagged fish were greater than those of the controls; on 7 October, rates of sham-tagged fish were lower than those of the controls; and on 10 October, rates of dummy radio tagged fish were lower than those of the controls. We concluded there was no apparent pattern in these differences.

Feeding and growth rates in the three groups were not found to be significantly different (Table 4). Although sham-tagged individuals consumed fewer minnows, a chi-square test showed no difference and a single-factor analysis of variance on the daily feeding rates of the groups indicated no significant differences among the groups.

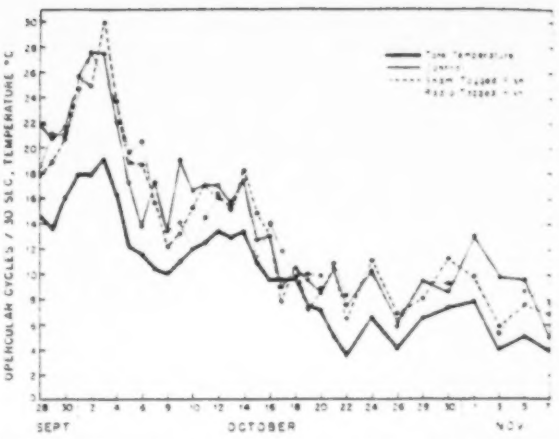

Fig. 2. Respiration rates of dummy radio tagged, sham-tagged, and Atkin-tagged control yellow perch at different ambient temperatures.

Table 4. Feeding and growth rates of yellow perch, 28 September to 11 Novembr 1976 (experiment 4).

Fish group[a]	Number of minnows consumed per group	Mean weight (g)		Mean weight change (%)
		Initial	Final	
Dummy radio tags	53	245	251	+2
Sham tags	25	270	245	-9
Controls	55	263	249	-5

[a] Five fish per group.

Two of five dummy radio tagged perch died during the 6-week respiration and feeding study. Sham-tagged and control fish did not suffer any mortality. One of the dead dummy radio tagged fish had a fungal infection near the anterior end of the dummy tag; the other also had a large fungal infection, but it was not associated with the tagging site. The anterior attachment wire had separated from one dummy radio tag; this break occurred at the junction of the wire and the epoxy shield covering the transmitter.

Experiment 5: Maximum Loading

Methods

The maximum tag weight an individual could carry was determined for five yellow perch. The weight of the dummy radio tag was increased by adding brass

washers and nuts to protruding bolts until the individual could no longer maintain equilibrium or swim normally in a holding tank.

Results

A linear regression of maximum package weight (in water) plotted against fish weight (Table 5) indicated that for fish in the range of 140 to 300 g, radio-tag weight should not exceed 1.5% of the fish's weight.

Table 5. Minimum tag weight resulting in loss of equilibrium in five yellow perch in a holding tank (experiment 5).

Fish weight (g)	Tag weight (g)		Tag weight in water as percent of fish weight
	In air	In water	
142	5.1	3.3	2.3
218	5.1	3.3	1.5
283	7.5	5.3	1.9
283	10.5	7.0	2.5
283	10.5	7.0	2.5
		Mean	2.1

Discussion

Telemetry studies generally collect a large number of observations on a relatively few individuals. The necessary assumption is that radio-tagged animals behave like individuals that have not undergone the tagging process or supported the additional burden of the tag. Mark-and-recapture studies with yellow perch in the upper Mississippi have resulted in a 9.6% recapture rate of 115 radio-tagged perch, compared with a 7.7% recapture rate of 903 Atkin-tagged perch (Ross and Siniff 1980); overnight fyke net catches of both radio-tagged and untagged fish were also observed and, on the average, the ratio of radio-tagged to untagged perch in the nets was 1:11. Gray and Haynes (1979) reported that travel times and percent returns of chinook salmon (*Oncorhynchus tshawytscha*) that retained external transmitters did not differ significantly from those of control fish in the Snake River. These findings support the premise that gross movements of radio-tagged fish are representative of those of untagged fish and that, in the less restricted natural environment, differential mortalities between radio-tagged and untagged groups may not be as serious as our pond studies suggest.

The experimental studies contrasting the responses of dummy radio tagged fish to those of controls and sham-tagged fish, however, revealed that the basic assumption on which radiotelemetry studies are founded should be accepted with reservations. In the present studies the biological effects of an external transmitter were revealed to consist of several elements: (1) Transmitter weight (in water) greater than 1.5% of the weight of the fish was found to be excessive. (2) Low concentrations of dissolved oxygen probably contributed to the high incidence of mortality in our survival study in the large pond, which suggests that environmental stresses compound tagging effects in radio-tagged fish. Mortality was also increased by entanglement of external transmitters in dense aquatic vegetation. (3) Selective predation on dummy radio tagged yellow perch suggests that any one or a combination of effects made the tagged fish more susceptible to predation by northern pike. These effects include residual trauma from tagging, which decreases a fish's ability to perceive and escape from a predator; increased visibility, and drag induced by an external transmitter; and entanglement in aquatic vegetation. Transmitters on potential prey fish should be as small, inconspicuous, and hydrodynamically efficient as possible. Design considerations should include an attachment wire at the extreme anterior end of external transmitters so that entanglement with aquatic vegetation is reduced. Camouflaging the transmitter by coloring it to blend with fish color might reduce its visibility. Although the size and configuration of transmitters are generally dictated by life and range considerations, the components should be arranged to optimize streamlining.

Laboratory experiments indicated that respiration rates and the growth and feeding behavior of yellow perch were not altered by dummy radio tags. Respiration rates varied directly and closely with temperature in all groups, but the lack of differences among groups suggests that dummy radio tagged perch were not required to alter their metabolic rates in order to carry the transmitter. In the largemouth bass study, however, feeding and growth were found to be nearly always greater among untagged fish. Responses by perch and bass may thus be species-specific or, at the lower temperatures in the perch experiment, it may be that more time would have been required to detect statistically significant differences.

In spite of the problems revealed in our studies, radiotelemetry may be the only means available for certain applications. The use of external transmitters should be considered for small gravid fish for which surgical implants are impractical, or for fish that regurgitate stomach implants. In such instances the problems must be taken into consideration when the findings are interpreted. Although physiological experiments do not directly provide information on behavioral changes induced by external transmitters, this type of testing can indicate problems that require adjustments in tag design and application.

Acknowlegments

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